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LASER-BASED ACOUSTO-OPTIC UPLINK COMMUNICATIONS TECHNIQUE

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) FLETCHER A. BLACKMON and (2) LYNN T. ANTONELLI, citizens of the United States of America, employees of the United States Government, (3) LEE E. ESTES and (4) GILBERT FAIN, citizens of the United States of America, and residents of (1) Forestdale, County of Barnstable, Commonwealth of Massachusetts, (2) Cranston, County of Kent, State of Rhode Island, (3) Mattapoisett, County of Plymouth, Commonwealth of Massachusetts, and (4) Freetown, County of Bristol, Commonwealth of Massachusetts, have invented certain new and useful improvements entitled as set forth above of which the following is a specification.

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PATENT TRADEMARK OFFICE

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3 LASER-BASED ACOUSTO-OPTIC UPLINK COMMUNICATIONS TECHNIQUE
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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 governmental purposes without the payment of any royalties
9 thereon or therefor.
10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The present invention relates to a method and an apparatus
14 for performing non-contact acousto-optic uplink communications.
15 More specifically, the present invention relates to a method and
16 an apparatus for enabling communication between a submerged
17 platform and an in-air platform via the transmission and
18 reception of acoustic and optical signals.

19 (2) Description of Related Prior Art

20 Traditionally, underwater acoustic telemetry involves all
21 in-water hardware to establish an acoustic communication link.
22 No known method of communications from a submerged platform to
23 an in-air platform exists. Conventionally, submerged platforms
24 such as submarines have to surface to transmit their data to an

1 in-air platform or remote site. This procedure can be time
2 consuming and inefficient as compared to a non-contact
3 communications scheme.

4 What is therefore needed is a technique for facilitating
5 the communication of information from an underwater platform to
6 an above-surface platform without establishing a physical link
7 or line of communication between the two.

8

9 SUMMARY OF THE INVENTION

10 Accordingly, it is an object of the present invention to
11 provide a method and apparatus for performing a non-contact
12 acousto-optic uplink communication.

13 In accordance with the present invention, an apparatus for
14 enabling acousto-optic communication comprises an in-water
15 platform emitting an acoustic signal to an acousto-optic
16 interaction zone. An in-air platform transmits a first
17 interrogation laser beam, a portion of the first interrogation
18 laser beam and a reflection of the first interrogation laser
19 beam from the acousto-optic interaction zone. The in-air
20 platform measures the differences between the received beams. A
21 plurality of optical interferences between the portion of the
22 first interrogation laser beam and the received second laser
23 beam are provided as output. A signal converter receives the

1 plurality of optical interferences and provides an electrical
2 signal representing the in-water acoustic communication signal.

3

4 BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 provides a schematic diagram of the acousto-optic
6 communication system of the present invention; and

7 FIG. 2 provides an illustration of the orientation and
8 implementation of the in-air and in-water platforms of the
9 present invention.

10

11 DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

12 This invention provides a non-contact laser-based sensor
13 acousto-optic communications uplink capability using the
14 concepts of laser Doppler vibrometry, i.e., optical
15 interrogation of the air-water interface, to detect velocity
16 perturbations which provide information on the signal structure
17 spectrum and time domain signal of the underwater acoustic
18 waveform.

19 With reference to FIG. 1 there is illustrated the apparatus
20 of the present invention. In-water platform 17 transmits an
21 acoustic telemetry signal 19 to an acousto-optic interaction
22 zone 21. In a preferred embodiment, in-water platform 17 is a
23 platform such as a submarine fully submerged in a body of water.
24 However, in-water platform 17 may be any platform submerged or

1 partially submerged in water including, but not limited to, sea
2 vessels, submersibles and remote sensing platforms. In a
3 preferred embodiment, the acoustic signal is comprised of a
4 scheme for underwater propagation such as multi-frequency shift
5 keying (MFSK), M-ary phase shift keying (M-PSK), or M-ary
6 quadrature amplitude modulation (M-QAM). In a preferred
7 embodiment, acoustic telemetry signal 19 is provided
8 electrically by a processor 18 to an acoustic projector 20 which
9 projects acoustic telemetry signal 19 into environmental water
10 31.

11 Acoustic telemetry signal 19 is emitted from in-water
12 platform 17 towards acousto-optic interaction zone 21. Acousto-
13 optic interaction zone 21 is contiguous to air-water boundary
14 27. In FIGS. 1 and 2, the air is indicated as 29 and the water
15 as 31. As such, part of acousto-optic interaction zone 21
16 consists of an area of the surface boundary between the air 29
17 and the water 31. The interaction of the acoustic telemetry
18 signal 19 with the acousto-optic interaction zone 21 causes
19 physical perturbations in the air-water, pressure release
20 boundary 27. These perturbations take the form of surface
21 vibrations.

22 In-air platform 11 transmits an optical interrogation laser
23 beam 25 created by a laser 32 towards the acousto-optic
24 interaction zone 21 at a time when the perturbations in the air-

1 water boundary 27 formed at the acousto-optic interaction zone
2 21 are expected. In a preferred embodiment, in-air platform 11
3 is a rotary winged aircraft capable of hovering over and in
4 proximity to acousto-optic interaction zone 21 as illustrated in
5 FIG. 2. While described in relation to a helicopter, the
6 present invention is not so limited. Rather, the in-air
7 platform of the present invention is broadly drawn to include
8 any platform located above the air-water boundary capable of
9 emitting an interrogation beam 25 including, but not limited to,
10 fixed wing aircraft, satellites, land based systems, and
11 portions of a sea vessel located above water.

12 The interrogation beam 25 is reflected off the air-water
13 boundary 27 and back to in-air platform 11 for reception as a
14 received reflection beam 23. Although, in the preferred
15 embodiment, interrogation beam 25 and reflection beam 23 are
16 transmitted and received at the same platform, different
17 platforms could be used for transmitting and receiving. Having
18 been formed from a reflection off of a surface experiencing
19 vibrational perturbations, received reflection beam 23 is laser
20 light altered to include numerous frequency shifts corresponding
21 to the vibrational perturbations of the acousto-optic
22 interaction zone 21.

23 Analysis of the received reflection beam 23 may be
24 performed to recover acoustic telemetry signal 19 using the

1 invention as claimed hereinafter. Laser Doppler vibrometry
2 refers to optical interrogations of the pressure release
3 interface and layers slightly below the surface to detect
4 velocity perturbations. A laser doppler vibrometer 36 is joined
5 to single sensor or a number of sensors 34 arranged to obtain
6 beam formable array data. A splitter 38 is used to divide out
7 unperturbed portion of the interrogation beam 25' from the
8 interrogation beam 25. The unperturbed beam portion 25' is used
9 as a reference to compare with received reflected beam 23. As
10 noted above, received reflection beam 23 is perturbed by the
11 vibrations in the air-water boundary 27 in contact with acousto-
12 optic interaction zone 21. The optical interference between the
13 two beams 23, 25 are measured as a Doppler velocity by an
14 interference vibrometer 36, which is then converted to an
15 electrical representation of the acoustic signal in the form of
16 an electrical signal by acoustic/photonic/electrical signal
17 converter 13. Acoustic/photonic/electrical signal converter 13
18 outputs the electrical signal to a telemetry receiver 15.
19 Telemetry receiver demodulates or otherwise decodes the
20 electrical signal to recreate the received acoustic telemetry
21 signal at the air-water interface.

22 Because the perturbations to the acousto-optic interaction
23 zone 21 occur over a finite time and space, advance knowledge of
24 the time and place to emit and receive optical interrogation

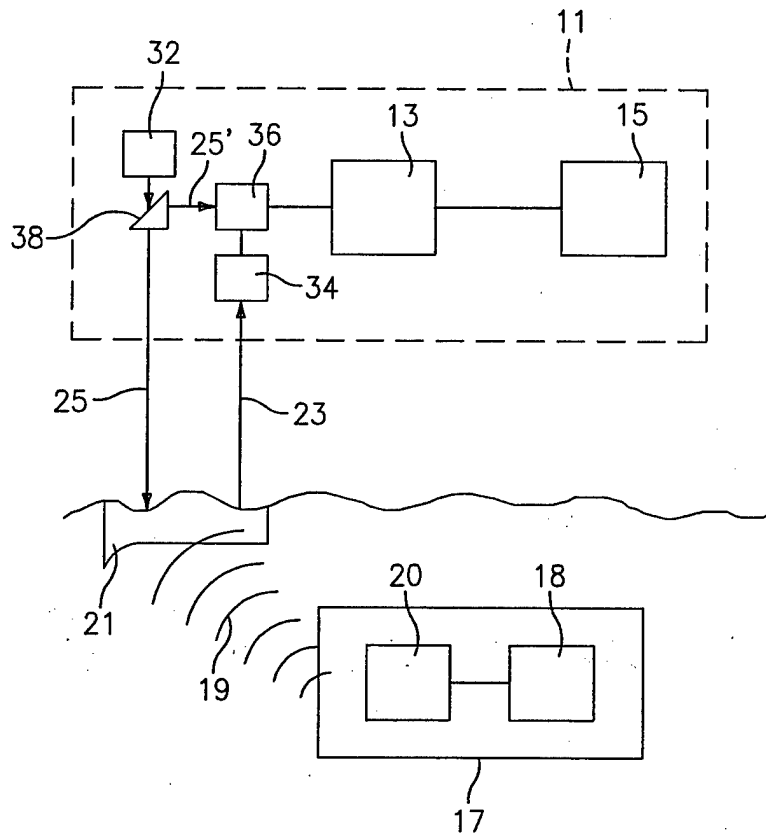
1 beams is generally required by the in-air platform 11. This
2 required knowledge adds a layer of data transmission security,
3 preventing unwanted parties from accessing the acoustic
4 telemetry signals 19. In addition, the sensing capability of
5 the present invention can be used for a number of related
6 applications such as threat/marine mammal detection.

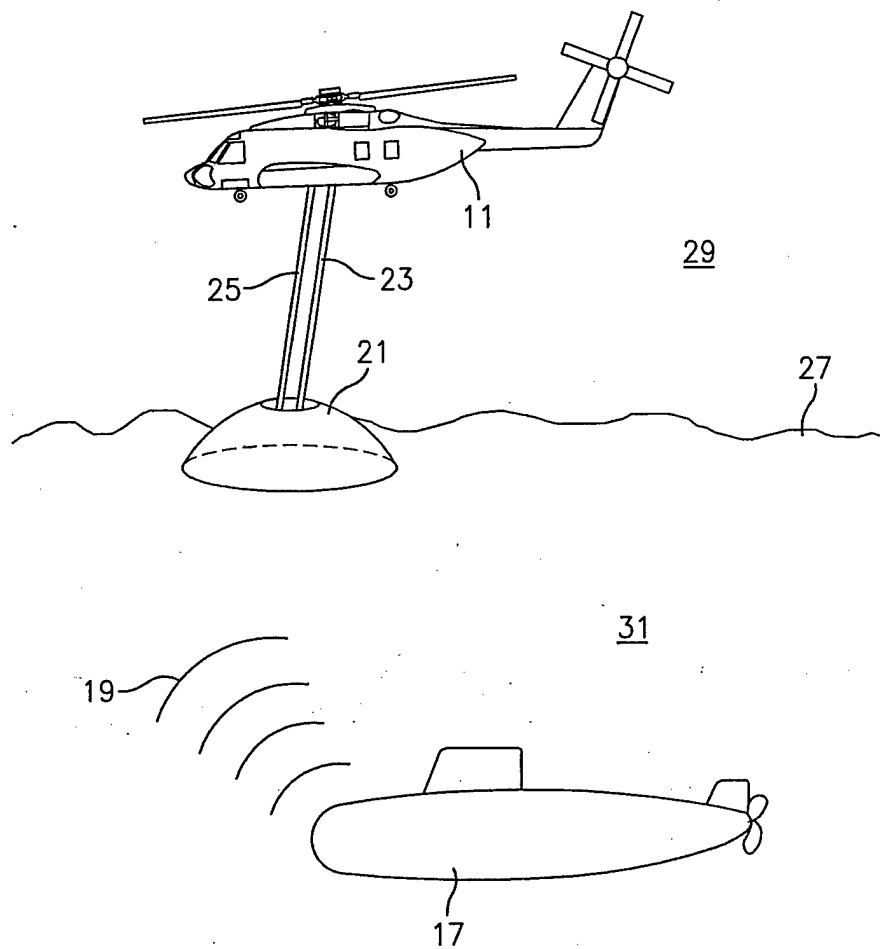
7 It is apparent that there has been provided in accordance
8 with the present invention an apparatus for performing a non-
9 contact acousto-optic uplink communications which fully
10 satisfies the objects, means, and advantages set forth
11 previously herein. While the present invention has been
12 described in the context of specific embodiments thereof, other
13 alternatives, modifications, and variations will become apparent
14 to those skilled in the art having read the foregoing
15 description. Accordingly, it is intended to embrace those
16 alternatives, modifications, and variations as fall within the
17 broad scope of the appended claims.

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5 ABSTRACT OF THE DISCLOSURE

6 An apparatus for enabling acousto-optic communication
7 comprising an in-water platform comprising means for emitting an
8 acoustic signal to an acousto-optic interaction zone, an in-air
9 platform comprising the ability for transmitting a first optical
10 interrogation beam, the ability for receiving a portion of the
11 first interrogation beam and a second laser beam formed from the
12 reflection of the first interrogation beam off of the acousto-
13 optic interaction zone, the ability for measuring and outputting
14 a plurality of optical interferences between the portion of the
15 first interrogation beam and the second reflected beam, and a
16 signal converter receiving as input the plurality of optical
17 interferences and outputting an electrical signal representing
18 the received acoustic telemetry signal at the interrogation
19 point at the air-water interface.

*FIG. 1*

**FIG. 2**